

Appendix C

Penetration Resistance Testing with the Becker Hammer Drill

C-1. Introduction

The use of the Becker hammer drill as an in situ penetration test for gravelly soils has gained widespread acceptance since its use was first reported (Harder and Seed 1986).¹ The Becker Penetration Test (BPT) for gravelly soils has become synonymous to the Standard Penetration Test (SPT) for sandy soils. However, the technology on use of the BPT for assessing engineering parameters is still evolving. The information presented herein is not the “how to do” cookbook approach, but rather it is a synopsis of the test procedures which are currently accepted and used as well as a list of variables that may affect the test results. Because standard procedures for conducting the BPT do not exist, it is recommended that the geotechnical engineer and/or the engineering geologist should peruse the literature and communicate with individuals knowledgeable on the use of the BPT prior to planning and conducting an investigation with the Becker hammer drill.

C-2. Equipment

The Becker hammer drill was devised specifically for use in sand, gravel, and boulders by Becker Drilling, LTD., of Canada. The drill utilizes a diesel-powered pile hammer to drive a double-wall casing into the ground without rotation. The elements of the Becker hammer drill include an air compressor, mud pump, a double- or single-acting diesel-powered hammer, rotary drive unit, hydraulic hoist, casing puller, mast, and cyclone. The double-wall threaded casing is specially fabricated from two heavy pipes which act as one unit. The casing has flush joints and tapered threads for making and breaking the string. Standard casings vary from 14.0- to 23-cm (5.5- to 9.0-in.) OD; the 17-cm- (6.6-in.-) diam casing is commonly used for the BPT. A toothed bit which is attached to the casing is used to break the material at the bottom of the borehole. The Becker hammer drill is discussed in Chapter 3.

¹ References cited in this appendix are included in Appendix A.

C-3. Sampling and Testing Procedures

Either an open bit or a plugged bit can be used to drive the casing. The BPT is conducted with a plugged bit, as experience has shown that questionable values of penetration resistance may be obtained if the open bit is used. To conduct the BPT, the number of hammer blows to drive the casing 0.3 m (1 ft) is counted and recorded. To use the BPT data, the blowcounts are converted to equivalent SPT blowcounts by empirical correlations (Harder and Seed 1986). From the equivalent SPT blowcounts, the penetration resistance can be correlated to selected geotechnical engineering parameters, such as liquefaction potential (Seed, Idriss, and Arango 1983; Seed et al. 1985).

The open bit is used for obtaining disturbed samples by the reverse circulation technique. As compressed air is pumped to the bottom of the hole through the annular space between the two pipes, broken fragments or cuttings are returned to the surface through the center of the casing. At the surface, the return flow is collected by a cyclone or collector buckets. The cuttings can be observed to give an idea of the materials which have been drilled. The sample should be interpreted cautiously, as it is a mixture of all soil materials from a given depth interval. If necessary, drilling can be stopped, and sampling can be conducted through the inner barrel using a split-barrel sampler or coring techniques. Procedures for documenting the results of the BPT (including sampling records and preservation of samples, if obtained) should follow the procedures which are described in Chapter 13.

C-4. Factors Which Affect the Becker Penetration Test

Harder and Seed (1986) initially believed that the bounce chamber pressure was a measure of the energy which was delivered to the penetrometer (casing). Upon further investigation, they determined that BPT blowcounts could not be predicted for different bounce chamber pressures. They determined that the energy which was developed was dependent on such factors as the combustion efficiency and conditions of the diesel hammer, atmospheric pressure, and the material response (including density, gradation, and overburden pressure) of the soil being penetrated.

Harder and Seed reported that the combustion efficiency was operator dependent. They reported that the operator could vary the throttle on the diesel hammer. They also found that the use of a rotary blower which forced air into the combustion cylinder resulted in a better burn (higher efficiency) of the fuel. Harder and Seed reported that the energy which was produced was dependent on combustion conditions, including fuel quantity and quality and the air mixture and pressure. For example, they suggested that the BPT could vary from 14 to 50 or more blows in the same material at the same depth if different combustion efficiencies were used. Hence, they concluded that the BPT had to be conducted under standard combustion conditions.

With respect to the effects of different atmospheric pressures, Harder and Seed reported that the energy which was delivered to the penetrometer (plugged bit) was a function of the pressure in the bounce chamber. For different atmospheric pressures, different bounce chamber pressures will result for the same hammer energy. Consequently, the measured bounce chamber pressures must be corrected for atmospheric conditions, especially when drilling operations are conducted at different elevations. To account for the effects of atmospheric pressures, Harder and Seed suggested that a ratio of theoretical impact kinetic energies for different atmospheric conditions could be used to normalize differences of delivered energies.

Harder and Seed also noted that the energy which was developed in the bounce chamber (blowcount) was dependent on the soil being penetrated. For low blowcount materials, the displacement of the casing was relatively large for each blow; much of the energy from the expanding combustion gases was lost to casing movement rather than raising the driving ram. As the blowcounts increased, Harder and Seed determined that more of the energy in the combustion chamber was transferred to the hammer; consequently, more energy was available to drive the penetrometer. Because of these findings, they suggested that a family of curves, i.e., site-specific

correlations, should be developed for a given drill rig and hammer to account for differences of bounce chamber pressures on BPT blowcount.

C-5. Summary

The BPT is a nonstandard test for which technology is evolving. Although BPT data must be adjusted to account for the effects of atmospheric conditions, material response, and overburden, the BPT blowcounts should be obtained using constant combustion conditions to the maximum extent possible. To interpret the test results and to use the penetration data for engineering purposes, Harder and Seed recommended that the adjusted BPT blowcounts should be converted to equivalent SPT blowcounts using empirical BPT-SPT correlations. The equivalent SPT blowcounts should then be normalized for the effects of overburden prior to correlating the equivalent blowcount data to the desired engineering parameters.

Although the BPT appears to be laden with numerous problems for conducting the test as well as interpretation of the data, the BPT is one of a very few in situ tests which can be used for assessing the engineering parameters of gravelly soils. (Geotechnical personnel are reminded that the SPT is used worldwide as an in situ test for sandy soils, although a number of variables which are discussed in Appendix B may affect the SPT results.) The principal advantage of the Becker hammer drill is that it offers a rapid and inexpensive method for drilling gravelly and bouldery materials. A principal disadvantage of the BPT test is that the in situ stress conditions may be altered significantly during the drilling process. For example, the flow of groundwater into the borehole can disturb the material at the bottom of the boring. Likewise, sand surrounding a boulder at the bottom of the borehole may be sucked into the casing as the hammer drilling is conducted; the results would be a nonrepresentative sample and a recovery ratio in excess of 100 percent.